Reclamation

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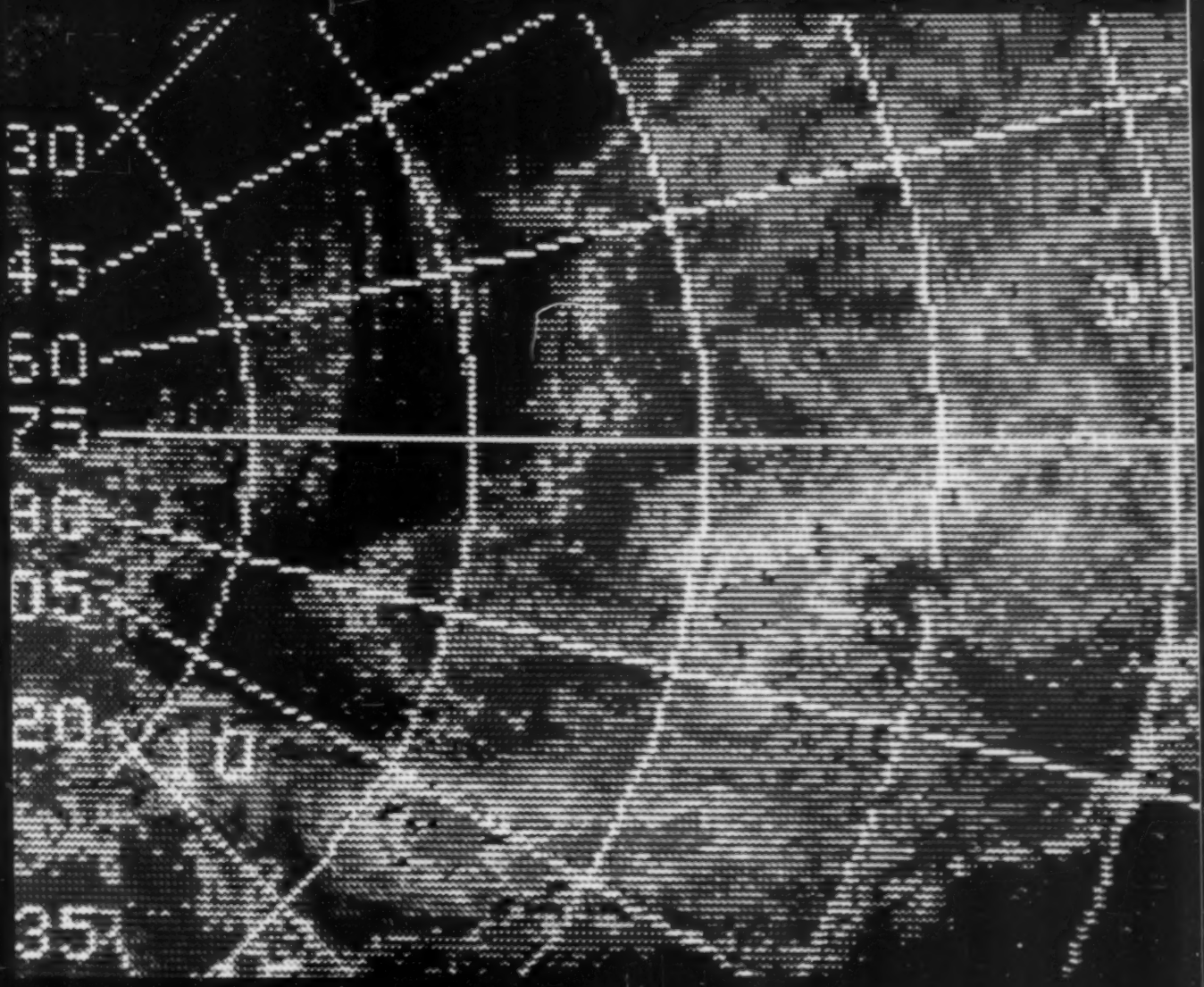

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

Two species of exotic waterweeds, hydrilla and eurasian watermilfoil, have grown into a multi-million dollar problem.

For the story, turn to page 17 and read about . . .

A Growing Menace

Studying Summer Skies

by Linda K. Woodworth

Summer and winter . . . times of marked contrast. Bustling activity, jam-packed days that go on and on, then shifting to a slower, more serene pace, quieted by a mantle of snow.

And so it is in Miles City, Montana, where in the summer of 1981 the Cooperative Convective Precipitation Experiment, the largest atmospheric field research experiment of its kind in the world to date, took place.

Photo by John Norquist

Linda K. Woodworth is a writer-editor in the Public Affairs Center, Denver, Colorado.

Photography by Robert A. Pauline, Photographic Coordinator for the Bureau of Reclamation, Public Affairs Center, Denver, Colorado.

NCAR Photo

The Cooperative Convective Precipitation Experiment is abbreviated to the acronym CCOPE and is pronounced "cope." It is a research effort designed to learn more about the weather systems that bring convective clouds, rain, hail and high winds to the High Plains, the agricultural heart of America. This summer's research will be followed by 2 years of data analysis and, if funding permits, by another field season in 1984.

But now, in winter, only a handful of scientists remain . . . a contrast to the nearly 300 men and women who shuttled in and out of this southeastern Montana town from May through August. Summer operations that stretched from predawn through stifling-hot afternoons, and often into the night have now returned to a more predictable office routine.

Much of the space-age equipment is gone, and the rolling hills and rugged buttes are once again brushed by the crisp, unrelenting winds of winter. The excitement of high-performance jet aircraft and their crews standing ready to probe developing rain clouds has subsided, leaving the necessary but less glamorous task of analyzing and interpreting some 125 billion pieces of atmospheric data.

The Basis

Numerous research efforts in the United States and around the world have shown the potential of cloud seeding to increase precipitation and reduce damaging hail. But scientists wanted to take a closer look at the many interacting components that form a cloud or storm. They wanted to learn what makes some storms more severe than others and how these potentially damage-producing storms may be predicted more accurately.

The need for a concentrated research effort was perceived by two scientists well known and respected in the atmospheric sciences field — Dr. Bernard Silverman, Chief of the Bureau of Reclamation's Division of Atmospheric Resources Research at the Engineering and Research Center in Denver, and Dr. Patrick Squires, Director of the Convective Storms Division, National Center for Atmospheric Research, Boulder, Colorado. Both men head prominent research efforts: Silverman's to develop a usable cloud seeding technology and Squires' to research the cloud processes that lead to rain and hail formation.

Specially instrumented aircraft probe the atmosphere to learn more about the processes that lead to formation of clouds, rain, hail and high winds.

Convective clouds are formed by air that is warmer than the surrounding air, so the warmer air rises to a point where its moisture condenses.

The Bureau's program involves cloud seeding research over mountainous areas to increase snowpack in winter, and over plains areas to add to summer rainfall. HIPLEX (the High Plains Cooperative Program), conducted by Reclamation since 1975, has advanced the scientific knowledge needed to develop summer cloud seeding techniques. Information gained from CCOPE is expected to further refine that knowledge.

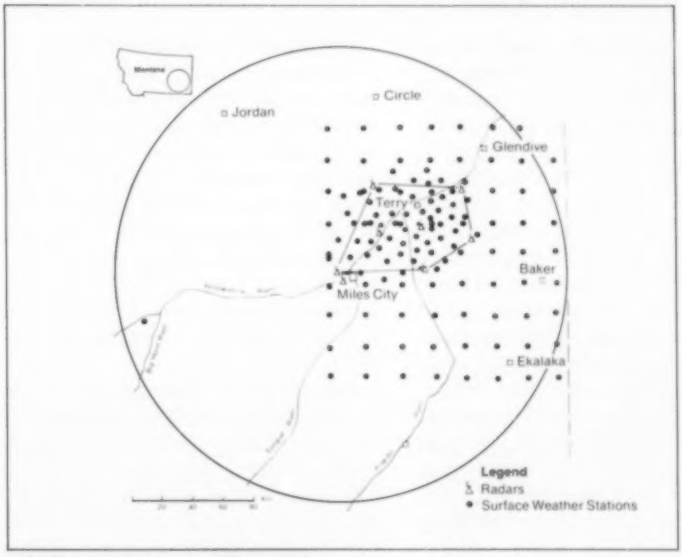
The Preparations

Beginning in the winter of 1978, Silverman and Squires formed the project that would bring some 300 scientists to a small Montana town in 1981. At succeeding workshops and planning sessions, CCOPE began to take shape, and interest in it grew rapidly. Atmospheric scientists across America and from foreign research laboratories wanted to share in this unique learning opportunity and many requested a part in it. The valuable human and technical resources that would be on hand demanded careful planning to gain maximum benefit.

In 1981, before packing their bags for Montana, the scientists knew exactly what they were to do that summer. Some would study the role of air motions that create storms — the updrafts, downdrafts and winds. Others would examine how water droplets, ice crystals and hailstones are formed and how they grow. Researchers were to focus on electrical charges in the atmosphere which influence rainfall, on atmospheric chemistry and on other vital components.

According to the plan, data gained through each specific study will be molded together to get a comprehensive picture

"Trailer City" B.C. (Before CCOPE). Eleven more transportable buildings were added for extra office space.



CCOPE study area — a 150-km radius circle (about 27,000 square miles) with Miles City roughly at the center.

In the operations center, scientists watch on computer terminals as a storm develops, and they direct aircraft flights in and around the storm.

of the birth, life and death of a summer storm. With a better understanding of how natural processes work, scientists can cooperate with nature to gain the best results from cloud seeding to increase precipitation or decrease hail. Since only 10 percent of the available water in the atmosphere falls as rain or snow, the potential of cloud seeding to add to available water supplies is great.

The Project Site

Winter winds bring snow in generous proportions to Miles City, located at the confluence of the Yellowstone and Tongue Rivers. At the community college, workers must shovel the roof to prevent collapse from the snow's weight. In the summer, the winds stir the dry, dusty air of the plains and sometimes bring clouds that promise moisture to the dryland farmers and ranchers. Miles City is a three-hour drive east of Billings. The town of 10,000 is a focal point in southeastern Montana for farmers and ranchers in surrounding areas, and the event of the year is the Bucking Horse Sale where rodeo stock changes hands.

The airport just outside of town has been the site of the Bureau's HIPLEX program, and a complex of trailers makes up the year-round office of Reclamation scientists stationed there.

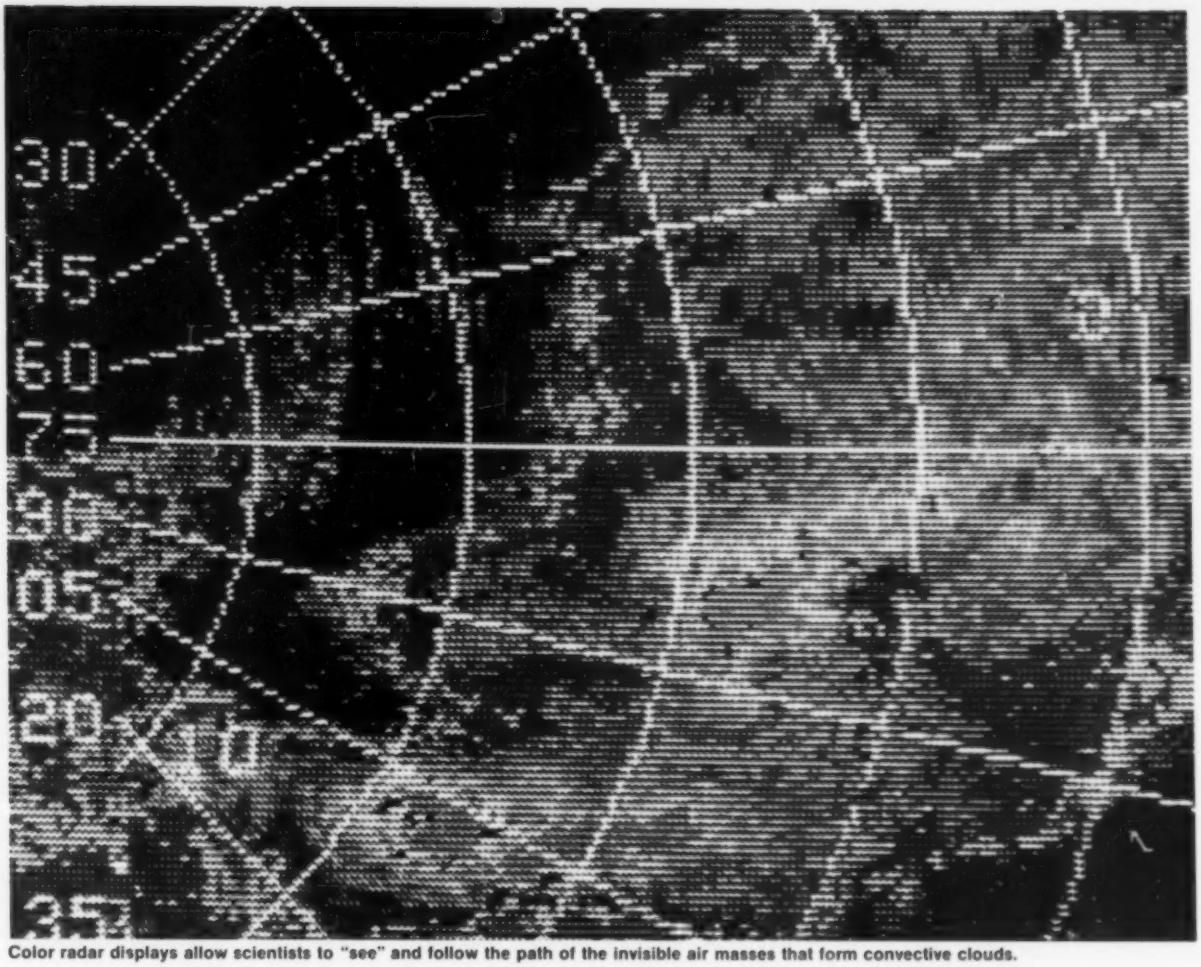
Preparations for CCOPE started early at the Miles City site. The HIPLEX director, Dr. Arlin Super, and his staff worked for months in advance to prepare for the influx of scientists and support personnel. An additional 11 trailers and transportable buildings were installed for office space. Housing and transportation needs were resolved to prevent logistics problems that could easily develop with so many "newcomers." Instrument locations were identified and made ready. For 125 ground-based weather stations, eight radar, 14 aircraft, and five balloon-launching sites, this was no small task! To anchor the trailer that would be the operations center required pouring a base of 160 cubic yards of concrete.

In May 1981 the scientists came to Miles City from universities, private research groups and government agencies. Nearly 30 organizations were represented — from the United States, Canada, Switzerland, Italy and England — an indication of the worldwide interest in and importance of CCOPE.

The Operations

The project presented the scientific challenge of identifying, describing and understanding the most important of many interactions that take place simultaneously in the atmosphere. By focusing different types of measuring systems on single clouds or storms, the researchers would be able to gain a more complete, overall view of the related components. No actual cloud seeding was done as all CCOPE studies centered on naturally occurring events.

The overhead weather laboratory of atmospheric scientists is constantly changing and hard to predict. Opportunities don't wait patiently in a test tube to be studied; instead they must



Color radar displays allow scientists to "see" and follow the path of the invisible air masses that form convective clouds.

be discovered early and pursued.

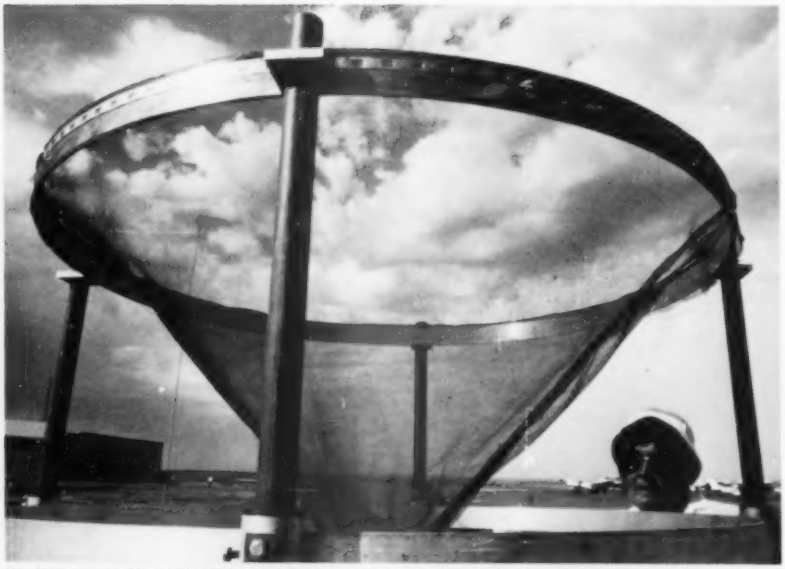
The storms over plains areas vary in character. Mature storms can be over 10 miles long, wide and high, and sometimes last for hours; while rain shower clouds are small and normally last about 20 minutes.

Scientists wanted to examine the convective clouds from their early beginnings, through the growth and precipitation stages, to eventual demise. They were on alert 24 hours a day, 7 days a week so as not to miss valuable opportunities for study.

Each morning at the field site, an experienced forecaster predicted the weather expected that day over the project area which encompasses about 27,000 square miles with Miles City roughly at the center. When "favorable" conditions occurred, crews trained their sophisticated equipment on the emerging clouds. (In this case, favorable means cloudy or stormy — a contradiction to our usual way of thinking.)

Solar-powered ground stations, advanced weather radar with multi-color display screens, high-performance aircraft with on-board computers . . . these and other instruments observed and recorded staggering quantities of data on clouds and their surrounding environment.

All activities of the scientists and instruments were coordinated at the operations center, which resembled the control room of a spaceship with eight display screens blinking a variety of colored images. The radar displays, which allowed scientists to track storms and direct aircraft, were transmitted to the screens from a 28-foot-diameter radar dish located alongside the operations center trailer. An inflated white dome, standing 60 feet high and protecting the tower-mounted radar dish from winds, looked like a huge puffball on the green Montana landscape.



Dr. Nancy Knight of the National Center for Atmospheric Research collects hailstones and analyzes them to learn how hail is formed.

On the ground throughout the project area, 125 weather stations measured temperature, humidity, pressure and other variables. Many of the stations used are solar-powered and automated, allowing operation in remote locations without human assistance. The stations transmitted their data by satellite to two Reclamation computers at the Engineering and Research Center in Denver which recorded the data for later analysis. Approximately 44 million individual observations were recorded.

In the air, as many as 10 of the 14 aircraft assembled for CCOPE probed the clouds at the same time. The fleet included an assortment of aircraft, all with different functions. A sailplane measured airflow without disrupting it, an armored T-28 military plane penetrated hailstorms, and sleek jets climbed swiftly to high altitudes to study conditions at cloud top. Cameras on the ground and mounted on planes used several thousand rolls and hundreds of reels of film to visually record cloud features.

Three high-level scientists alternated at coordinating these many complex, concurrent activities at the CCOPE site. One was the Bureau's Dr. Arlin Super and two were from the National Center for Atmospheric Research, Drs. Charles Knight and Brant Foote.

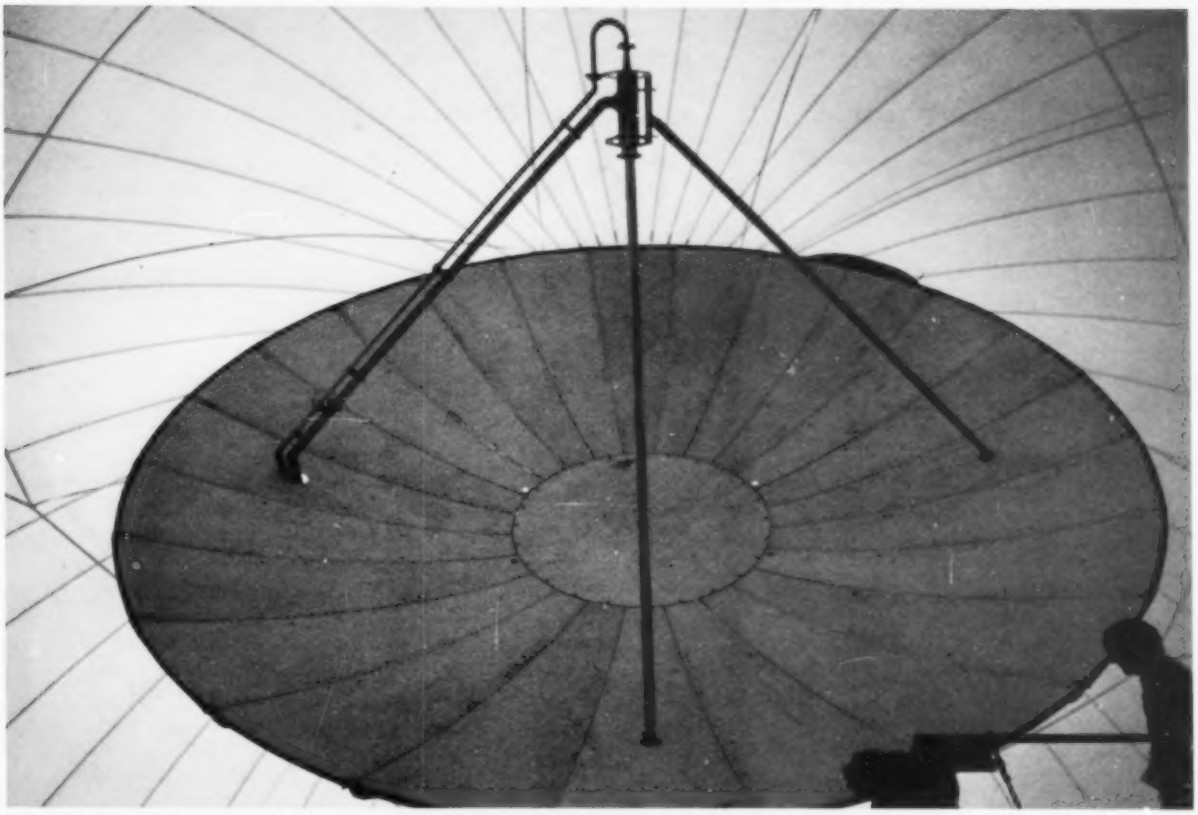
On days with "favorably" stormy weather, the designated operations director would be busy juggling the many priorities of CCOPE.

Despite the hectic schedule, each operations director found time to answer questions from visitors and the news media. A project with the magnitude of CCOPE does not go without notice among newspaper and broadcast journalists. Reporters from the *New York Times*, the *Los Angeles Times*, the *Miles City Star* and the *Christian Science Monitor*, the *National Geographic* and *Newsweek*, the *Denver Post* and *Rocky Mountain News* . . . all wrote about the weather and the scientists studying it. Filming crews from two national networks, the Public Broadcasting System and television stations in neighboring states poked their lenses over scientists' shoulders and followed them in their work.

The summer of 1981 offered many good opportunities for study. The weather was so cooperative, in fact, that money for aircraft flights threatened to run out before the project's completion. To carry on operations, the Bureau and NCAR committed additional funds —a vote of confidence for the scientists and their history-making work.

Of 82 days in the study period, data was obtained on 72 days, a remarkably high number con-

A dome some 60-feet high protects the radar dish from high winds at the operations center.



A 28-foot radar dish rotates inside the inflated dome and transmits its data to display screens.

Dr. Arlin Super (right), one of three CCOPE operations directors, discusses plans for the day with another scientist.

sidering the unpredictability of summer storms. A total of 244 separate experiments were conducted on various atmospheric components, 107 of which were considered "core" or vital to the goal of the project. The remaining 137 experiments involved special purpose studies that will enhance understanding of atmospheric processes.

Researchers are now reviewing 5,000 magnetic tapes, each with some 25 million characters of meteorological data collected by radar, aircraft and other equipment.

The Payoff

The payoff from CCOPE will come when the data collected is analyzed and interpreted. The results will provide more knowledge about weather, allowing scientists to better predict and modify it for the good of our world.

Seeding to reduce hail can result in the savings of millions of dollars each year. In 1980, farmers reported crop losses from hail to be over $400 million.

Studies have shown that an additional one-to-two inches of growing-season rainfall expected from cloud seeding can add substantially to revenues throughout the High Plains. North and South Dakota can realize direct benefits of at least $50 million each, with similar amounts anticipated throughout the region.

When rain falls directly on crops, there is less demand for irrigation from Reclamation's reservoirs, a feature that is especially valuable in times of water shortage. Also, less water is required from underground supplies, such as the Ogallala Aquifer which is threatened by high irrigation demands. More "atmospheric water" on crops can reduce the energy costs farmers now pay to pump water from that dwindling reservoir.

More moisture from the skies means more water for all purposes — cities, agriculture, industry, energy, recreation and the natural environment.

In 1980, Reclamation delivered over 30 million acre-feet of water, all of which was at one time or another processed through clouds. Clouds are an important source of water, and cloud seeding research has been part of the Bureau of Reclamation since the early 1960's. When a scientifically sound cloud seeding technology is available, it can be used to add to water supplies behind Reclamation dams as well as to increase direct rainfall on growing crops and rangelands.

The Next Step

Now, in the Montana winter, Arlin Super surveys the hills and buttes from his office at "trailer city." He and his staff, along with many other scientists in Denver, Boulder and elsewhere, have had a brief moment to pause, reflect and catch their breath. But now the real work begins — tackling the mountain of data that was collected in the summer of '81, the data that will yield the answers they seek.

And perhaps in the summer of 1984, if some answers have been found and the budget permits, they'll do it all again . . . seeking more knowledge about that elusive, evasive, extremely important part of our world, the atmosphere.

Weather balloons measure such things as temperature, humidity and pressure in the atmosphere and transmit the data to scientists on the ground.

A Growing Menace

by John C. Pringle, Jr., Fred L. Nibling, Jr., and Joan S. Thullen

Photo by John Norquist

Fred L. Nibling John C. Pringle, Jr. Joan S. Thullen

John C. Pringle is the supervisor-coordinator and Fred L. Nibling and Joan S. Thullen are botanists for the Aquatic Site Pest Control Group, Environmental Sciences Section, Division of Research, Engineering and Research Center, Denver, Colorado.

Photography by Fred Nibling, Joan Thullen, Tom Parks, Wayne Lambert, Engineering and Research Center, Denver; Robert A. Pauline, Public Affairs Center, Denver; Max Groom, Gene Hertzog, Lower Colorado Region, Boulder City, Nevada; Robert Leonard, Pacific-Northwest Region, Boise, Idaho; California Department of Food and Agriculture.

There are hundreds of thousands of miles of canals and waterways in the West. A majority of these water systems are plagued by a dilemma little known or understood by the average citizen. Annually aquatic weeds create problems requiring expenditures well into millions of dollars for weed control. Research is currently under way to study the pattern of weed growth in waterways and to determine methods of controlling this aquatic menace which limits and obstructs water flow.

One may ask why the waterweed problem should affect him or why a steelworker in Pittsburgh or a schoolteacher in New York should care about the West's problem with waterweeds. Waterweeds create problems which affect *everyone*. We all rely on some portion of a water resources system, yet few of us are aware of the possible impacts these organisms have on our lives.

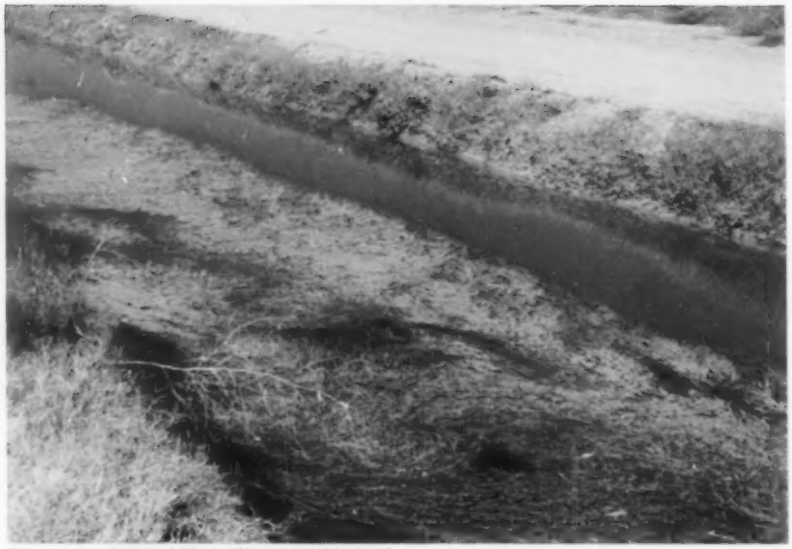
Costs for aquatic weed control incurred by irrigation and water districts are passed on to farmers and other consumers. Likewise, farmers pass on their water use costs to the public through increases in the prices for food and other agricultural crops. The public, in some areas, may pay not only once but twice for the damage caused by waterweeds, once in their home water bill and again in the supermarket.

Consumers buying winter lettuce grown in southern California or potatoes grown in Idaho have a stake in the cost of producing these commodities. Developing the energy resources in the West is also dependent on a reliable, continuing source of water. We are *all* drawing water from a common limited source. Water loss or waste due to aquatic weeds in one area will lessen the amount of water available for use by others downstream. Water resources in the West are used in many different but interconnected ways so that factors which affect only one portion of the water available will eventually affect the resource as a whole.

Perhaps one of the reasons why the public is so unaware of waterweed problems is the past success most irrigation and other water systems operators have had in controlling weed problems. Several sociological and biological changes have occurred in recent decades which are just now beginning to reach a stage where they might seriously affect water

system operations. The general cost of operating weed control programs has greatly increased over the past decade. Energy costs have more than doubled. Costs of labor and machinery used to clear waterways have also risen. Some chemicals are becoming scarce, others are environmentally unacceptable, and still others are not economical since many of their components are used in more profitable commodities such as energy products.

In recent years, an increased public awareness of natural resources has surfaced, bringing about changes in attitudes and policies which influence western water resources. Many water systems once intended for irrigation only are now being used for multiple purposes. Changes in population distribution in our country have transformed rural communities into urban centers and, as a consequence, there has been a trend toward using irrigation systems as sources for public water supplies. Additionally, many waterways have become established as wildlife habitats which, on occasion, has placed system operation goals in direct conflict with wildlife management interests.



A pure stand of hydrilla in Wormwood Lateral.

Researchers have found a variety of problems caused by aquatic weeds. The most serious effect is the impact on the nation's food supply. Infestations of aggressive aquatic weeds in irrigation channels may interrupt water deliveries and result in crop failures. Weeds can block navigation channels, hinder commercial fishing, destroy wildlife habitat, damage recreation areas, serve as breeding grounds for disease-bearing organisms such as mosquitos and kill beneficial aquatic organisms.

Aquatic weeds affect irrigation systems in a variety of ways depending on their degree of infestation. Areas which have aquatic weed problems must be maintained continuously to keep water channels in good operating condition. Even a moderate weed stand in a canal can slow the water velocity, decrease the water-carrying capacity of the canal and result in overflowing, flooding and delays in water service. In desert climates, timing of crop watering is critical. Lack of water for just a few days on a lettuce crop, for example, may cause serious reduction in yield or even loss of the entire crop.

Researchers record hydrilla density readings. The readings will be used to evaluate herbicide treatments.

To prevent this potential destruction of property and crops, water system operators must maintain continual surveillance.

Loss of velocity also reduces the sediment-carrying capacity of irrigation water, causing bars and dunes to form with subsequent reduction in the size of the channel. The buildup of silt bars provides shallow water habitat which enhances the growth of emergent vegetation. This type of vegetation contributes to water loss by evaporation through its leaves. Aquatic weed stands can also cause a current shift in canals leading to bank undercutting. If left unrepaired, eventual loss of the embankment may result in flooding.

Multiple-use water systems present the greatest obstacles to aquatic weed control efforts. When water systems are used as public water supply, the water is considered a food product and, consequently, any chemical used to control aquatic vegetation must be approved by Federal and state agencies. The chemicals must meet certain potability requirements and specified residue tolerance levels. Likewise, if the water is to be used to irrigate crops, any chemical aquatic weed control technique must not adversely affect the crops. Chemical residues must remain below levels prescribed by Federal and state regulations. With increased water scarcity, irrigation system operators are reluctant to waste water. As a result, there is a decline in using weed controls to manage drainage of treated water into wasteways. Also, possible impacts of aquatic weed control measures on fish and wildlife in a water system must be considered. In areas where environmental resources may be adversely affected by chemical weed control measures, alternate techniques must be used.

The physical characteristics of a particular system add to the aquatic weed control problem. In many areas, reserves are not available to sustain more than a few days interruption in the water supply. Consequently, draining or ponding waterways to treat weed problems is not always acceptable. Additionally, systems which must continue to flow carry sediment loads which can deactivate herbicides, thereby limiting their effectiveness. Flowing water also dilutes herbicide applications and restricts the

Eurasian watermilfoil covers the water at Evergreen Reservoir near Ephrata, Washington. This particular infestation illustrates the high density biomass that can accumulate in a reservoir.

Reclamation biologists measure water quality with a Hydrolab instrument. Such tests tell researchers the environmental conditions in which the weeds are growing.

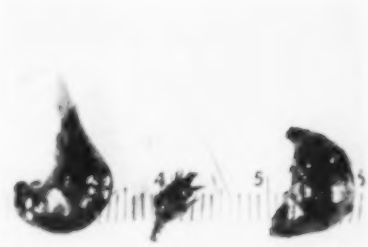
time aquatic weeds are exposed to a particular treatment.

Chemical characteristics of the water in a system also affect the success of herbicide treatments. For example, water with high bicarbonate alkalinity limits the effectiveness of such compounds as copper sulfate for algae and aquatic weed control. Low water temperature slows metabolism of aquatic plants which, in turn, reduces the effect of herbicide treatments.

Two recently discovered aquatic menaces — hydrilla and eurasian watermilfoil — have invaded western U.S. waterways and are challenging scientists' past successes in weed control. These aquatic weeds are difficult to control by chemical and other measures because of biological characteristics which aid their survival.

Hydrilla and eurasian watermilfoil are capable of "explosive" growth rates which can stop the flow of water through a channel in a matter of months. They can survive in a wide range of conditions and are capable of growing at low light levels. By forming light-excluding canopies they may prevent the growth of other weed species. These two species survive well during periods of stress or exposure to drying, and their rapid growth rate

A Fish and Wildlife Service biological technician tests rainbow trout and other aquatic organisms for toxicity to fluridone. Fluridone is an experimental herbicide which is currently being evaluated for control of aquatic vegetation.



These hydrilla tubers and turion enable the weed to survive long winters or dry periods. The tubers form on underground stems. The turion (second from left) forms on the hydrilla leaves.

allows them to compete for such necessary resources as nutrients, light and space.

It will take persistent research to develop methods to successfully control these weeds. Presently, no chemical methods are available for extensive hydrilla control in irrigation canals.

In fact, in some circumstances there is evidence to suggest that certain herbicide treatments may enhance hydrilla fragmentation and increase its rate of spread.

Clearly, the resources of any one agency are too limited to handle the whole problem; therefore, several Federal and state agencies have combined their efforts to find a way to rid our waterways of hydrilla and eurasian watermilfoil.

A cooperative aquatic weed research program with the Bureau of Reclamation's Division of Research, the U.S. Fish and Wildlife Service and the Department of Agriculture's Agricultural Research Service has been ongoing for many years. The Agricultural Research Service is currently investigating the physiology of hydrilla and other aquatic weeds to determine the most advantageous means of chemical control. The Fish and Wildlife Service, in cooperation with the Bureau of Reclamation, is evaluating hybrid grass carp in both laboratory and field studies. Efforts are concentrated on determination of feeding rates and food preferences of the experimental fish. In other research areas, Fish and Wildlife personnel are conducting toxicological evaluations of various aquatic herbicides and other chemicals on natural fish populations.

This consolidated effort combines the disciplines of aquatic weed control, aquatic plant physiology and fisheries management. The overall goal of the program is to develop effective ways of controlling aquatic weeds while limiting adverse environmental impacts.

In addition to the above agencies, several others including the Department of Agriculture's Animal and Plant Health Inspection Service, California Department of Food and Agriculture, California Department of Fish and Game, Imperial County Agriculture Department, the Imperial Irrigation District and the Coachella Valley Water District have joined forces in an effort to control the growth and spread of hydrilla in the fertile Imperial Valley of California.

Scuba diving has recently been incorporated into the research programs at the Engineering and Research Center in Denver for studying aquatic weeds and evaluating aquatic weed control methods. The Bureau is fortunate to have several well-equipped underwater investigation teams which perform a variety of duties ranging from inspection of deep water dam structures to various geological and environmental surveys. The underwater investigation team from Reclamation's Lower Colorado Region located in Boulder City, Nevada, has been an integral part of a study by the Engineering and Research Center to evaluate various aquatic weed control techniques in the Imperial Irrigation District and the Coachella Valley Water District in southern California.

This traveling weed screen on the Coachella Canal serves a dual purpose. It prevents hybrid grass carp from traveling upstream and it clears loose weeds from the canal. The pile of weeds behind the screen represents only a day or two of accumulation.

The advantages of scuba diving in aquatic weed research are significant. Scuba diving enables scientists to observe aquatic weeds in their natural habitat. This is particularly important when conducting surveys to assess herbicide or herbivorous fish effectiveness, or to make life cycle observations of aquatic vegetation. The mobility of the scientist-diver allows collection of ecological evaluations such as biomass sampling to accurately quantify vegetation in aquatic weed stands. Divers can perform these surveys in areas not visible from the shore, such as canal bottoms. Using scuba divers allows mapping of vegetation stands and monitoring growth or productivity of underwater vegetation.

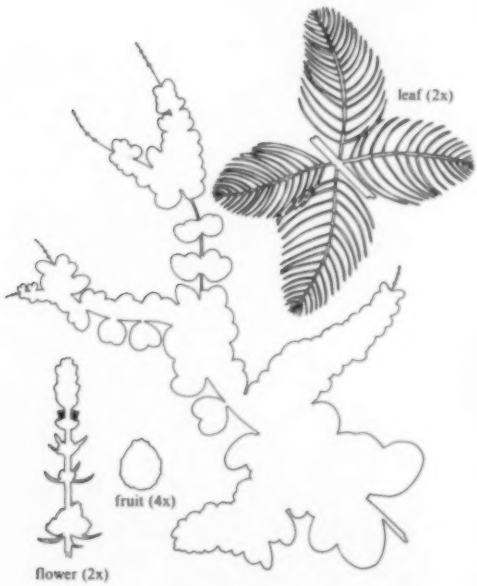
The use of plant-consuming — or herbivorous — fish to control aquatic vegetation is a relatively new technology in the

Eurasian watermilfoil
Myriophyllum spicatum L.

Eurasian watermilfoil has become a real problem in lakes, streams and irrigation systems in the United States. First found in the Chesapeake Bay of Maryland and Virginia in the late 1800's, it is believed to have come from northern Europe.

Eurasian watermilfoil grows completely submerged except for the flowering spikes. The stems are branched slightly and can vary in color from a pale greenish-yellow to a full pink. The leaves are separated into 12 to 24 pairs of filament-like divisions, and develop on the stem usually four in a whorl. The flowers are small and are usually in whorls of four along a slender terminal spike which extends above the water's surface. All but the lower two to four whorls of floral bracts (leaves beneath and enclosing the flowers) have smooth edges. The lower floral bracts have comb-like or serrated edges, and are equal to or longer than the fruits. Eurasian watermilfoil has developed small, specialized land forms that survive periods of dryness or water drawdown.

Like hydrilla, eurasian watermilfoil colonizes new sites mainly by vegetative fragments which develop roots and sink to establish new plants. And, it is very difficult to control.



The magnification notations refer to the illustration on the reverse page.

Eurasian Watermilfoil *Myriophyllum spicatum* L.

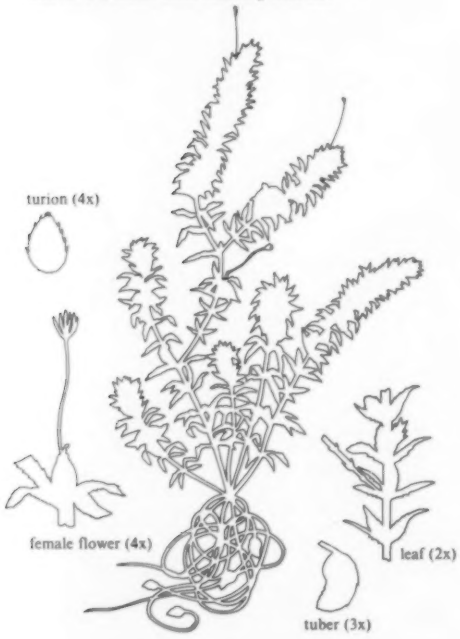
Hydrilla *Hydrilla verticillata* Royal

Hydrilla
Hydrilla verticillata Royle

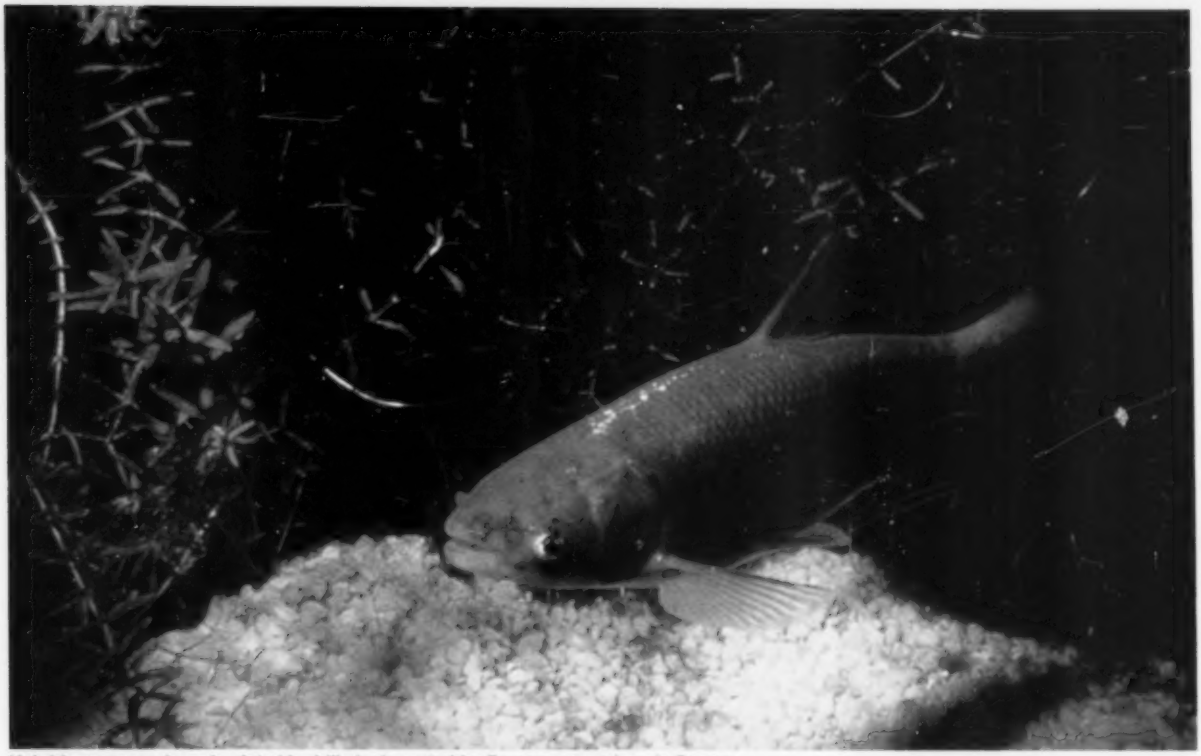
Hydrilla is an extremely prolific aquatic plant that has infested millions of acres of lakes, rivers and irrigation systems throughout the United States. It is a tropical plant which is not native to the United States. Hydrilla was originally imported for aquarium use. In 1960 it was discovered infesting a Florida river and drainage canal.

Several characteristics help identify hydrilla. It has two to eight leaves per whorl along its long branching stems. Hydrilla has one to three tiny spines along the central vein on the underside of spear-shaped serrated leaves. Turions form in the angle between the leaves and branch stems. Potato-like tubers appear in the soil on the ends of rhizomes. Small, white, female flowers with six simple petals appear at or near the water's surface in late summer or early fall. Male flowers and consequently fruits, have not been observed in the United States.

Hydrilla reproduces by vegetative fragments. These fragments from the plant can be carried to uninfested areas by boaters, fishermen and vacationers. Control is very difficult because parts of the plant (turions and tubers) are able to survive winter and stress periods.



The magnification notations refer to the illustration on the reverse page.



Hybrid grass carp in a simulated hydrilla bed created by Bureau researchers in Denver.

United States, even though the Chinese have been using the grass carp for this purpose for centuries. The name "carp" carries a negative connotation, and many people erroneously assume a close similarity to the common carp. Although both fish are members of the minnow family, they are quite dissimilar, particularly with respect to their feeding habits. Common carp are bottom scavengers, consuming organisms which dwell in the mud bottoms of lakes and streams. Feeding activities of common carp disturb sediment which clouds the water and may be detrimental to other forms of aquatic wildlife. Grass carp, on the other hand, are essentially herbivorous; that is, they consume plants.

Possible adverse effects of grass carp must be considered, however, before they can be introduced into our irrigation systems. It is possible that grass carp could escape the confines of irrigation systems, enter natural waterways and establish sustaining populations which could threaten native fishes. Introducing nonnative species without considering their possible impact on the environment has often led to undesirable consequences. For example, when the hare was introduced to Australia and the European starling and common carp to North America, the natural forces which regulated their numbers in their native environments were missing in the new habitats, resulting in population explosions. Very similar circumstances occurred when hydrilla and eurasian watermilfoil were brought to this country. In the absence of natural enemies or competition to keep them in check, they have spread rapidly.

Recently, however, a discovery has been made which may allay many of the environmental concerns about potential detrimental effects caused by the grass carp. In Hungary, a practical means of producing a sterile hybrid grass carp has been developed. This fish is the product of crossbreeding a female grass carp with a male bighead carp, another fish of Asian origin. This sterile hybrid offspring has generated considerable interest for several reasons. The fish are functionally like their grass carp parent in that they consume aquatic vegetation; however, they are sterile.

In theory, hybrid grass carp could be one of the better ways to control aquatic weeds with minimal environmental consequences. Irrigation districts and other water delivery organizations would have a fish capable

The beauty of the hydrilla plant belies its aggressive assault on America's waterways. Note the serrated leaf and spiny projections on the underside.

Eurasian watermilfoil develops on land. This specialized adaptation allows plants to survive long periods without water.

of controlling aquatic weeds while environmental management agencies would not have the concern of its reproduction and potential development into an uncontrolled population.

A three-year study in the Imperial Irrigation District and the Coachella Valley Water District in southern California to evaluate the hybrid grass carp is currently under way. This study program is an ideal example of how irrigation districts and government agencies can cooperatively work together to develop a new technology. Participants in the study include the Bureau of Reclamation, U.S. Fish and Wildlife Service, the Coachella Valley Water District, Imperial Irrigation District, California Department of Fish and Game, California Department of Water Resources and California Department of Food and Agriculture. Studies are being conducted in the Coachella Canal of the Coachella Valley Water District, in a lateral of the Wormwood Canal in the Imperial Irrigation District and in other facilities. Both the Coachella and Wormwood Canals are inhabited by eurasian watermilfoil as well as sago pondweed, another common aquatic weed pest. In addition to these two species, the Imperial Irrigation District has large amounts of hydrilla in the hybrid grass carp study area.

The two study sites were purposely selected for their difference in size and operational characteristics. The test area in the Imperial Irrigation District is situated in a small lateral canal where the maximum water delivery capacity is 60 cubic feet per second. The

Coachella Canal has a substantially larger delivery capacity of 1,600 cubic feet per second and provides the main water supply serving the Coachella Irrigation District.

Each study canal is divided into four test areas where aquatic weed infestations are evaluated based on the effects of hybrid grass carp on plant biomass, density and tuber production. Tubers, bulb-like root forms, develop deep in the hydrosoil and are relatively inaccessible to herbicidal controls. A record is being kept of weed growth patterns and abundance in the study areas.

Studies are also being conducted to determine the effect of hybrid grass carp on other organisms inhabiting the canal systems, including the size and population distribution of other established fish species. Investigations will also determine the influence of these herbivorous fish on various components of the aquatic food chain such as aquatic insects living in the weed stands.

Prestocking baseline studies were conducted in the 1980 growing season. Information gathered from these preliminary investigations was used to establish population densities and distributions of both plant and animal species in the canals. With the stocking of the hybrid grass carp during the summer of 1981, the study entered a two-year field evaluation phase in which both the effectiveness of the fish and its environmental compatibility will be measured.

A helicopter drops herbicide "Komeen" in the All-American Canal in an attempt by the California Department of Food and Agriculture and the Imperial Irrigation District to control hydrilla.

Wormwood Canal is dry and apparently free from weeds after being mechanically dredged.

These hybrid grass carp are feeding on eurasian watermilfoil in a Reclamation test facility.

A diver explores the subsurface environment. It takes time and experience for a diver to develop confidence and appreciation for the deep.

Guardians of Western Water

by Richard A. Crysdale

Three scuba divers enter the frigid waters of Twin Lakes in Colorado's high country. One diver remains on the surface; the other two sink out of sight. Even with high-powered underwater lamps, visibility is about six inches. Slowly, they move through the powerplant's narrow intakes, inspecting the structure as they sink and looking for construction debris on the silt-lined bottom.

Richard A. Crysdale is an Outdoor Recreation Planner, Division of O&M Technical Services, at the Engineering and Research Center, Denver, Colorado. He also serves as chairman of the Bureau's Diving Advisory Committee which administers the Bureau's underwater inspection program.

Photography by Richard Crysdale, Fred Nibling, Engineering and Research Center, Denver, Colorado; Max Groom and Gene Hertzog, Lower Colorado Region, Boulder City, Nevada.

The divers hang on to their tether line. Loss of contact with the line or dive partner can push a diver over the threshold of fear, one of a diver's worst unseen enemies. These divers, though, have been carefully trained and are skilled beyond normal diving requirements. They are members of the Bureau of Reclamation's dive team.

During the last 17 years, Reclamation divers have logged over 20,000 accident-free hours of "bottom time." These volunteers have registered most of this time in canals, siphons, stilling basins, intake pipes, rivers and reservoirs, encountering water hazards unknown to clearwater divers. Most divers do not dive in cold water, swim in zero visibility, restrictive areas or at high altitudes. That's what makes the Reclamation divers unique. And, it's no accident that these volunteers have logged such a remarkable safety record.

For the past 14 years, Bureau divers have attended a biennial scuba diving seminar. In 1981 the divers attended classes specifically designed for them by the Mid-Pacific Region (the seminar host region), the Professional Association of Diving Instructors (PADI) and the University of Southern California. The week-long seminar was held in June at the University of Southern California's Marine Science Center on Santa Catalina Island.

Dennis Graver, Robert Wohlers, both seminar instructors from PADI, and Max Groom, Reclamation's master diver from the Lower Colorado Region, conducted the training classes and diving exercises. Dr. Andy Pilmanis is a medical doctor specializing in hyperbaric medicine and operates the University's decompression chamber to treat air embolism, the bends and other decompression sicknesses. Bureau dive team leaders and senior divers conducted seminar discussions about inspection techniques used for dams, siphons, canals, rivers and many other underwater predicaments. Don Nelson, a veteran siphon diver from the Mid-Pacific Region says, "You never know what you may run into in those dark 12-foot pipes . . . animal carcasses, car bodies, barbed wire, bunches of tumble weeds . . . . They all interrupt the flow of water. Someone has to find out what the problem is and recommend how to safely remove it without damaging the pipes."

Tom Spicher (PN Region), Jim Andrews (MP Region) and Brent Carter (PN Region) represent over 51 years of Bureau diving experience since the teams were established in 1954.

Diving partners check in and out of the water, telling a surface recorder (Max Groom) their time, depth and tank air pressure.

During a night dive exercise to simulate structure diving conditions, the divers experimented with new lightweight lamps and compared them to the old reliables. One gasket leak or switch failure can subject the diver to total darkness and disorientation. That beam of light is frequently the only contact thread a diver has with his buddy — and he needs to be confident that it's going to work! Miniature cameras with self-advancing film were tested by divers to find out how useful they would be for recording the condition of a structure.

These tiny cameras would be handy to record cavitation of turbines, impellers or lined stilling basins. Every piece of equipment a diver uses must be reliable. Divers, who usually pack 80 to 90 pounds of equipment, also welcome the opportunity to try out lighter, more compact equipment.

Max Groom, the Lower Colorado Region dive team leader and PADI master diver, designed and built a diving bell

A kalaidascope of illumasticks and underwater lanterns enable the divers to see one another in the water at night.

which he brought to the seminar for experimentation. During an underwater obstacle course exercise, the divers were able to verbally communicate with one another in 40 feet of water using the bell. The divers could also use the bell to communicate with surface tenders. Innovations such as the diving bell can prolong the divers' bottom time, enabling them to do a more thorough inspection.

Cardiopulmonary resuscitation (CPR) is a skill in itself. The divers learned how to administer mouth-to-mouth resuscitation in the water. Diving equipment was systematically stripped from the victim so the rescuer could conserve strength and move toward shore. Ropes were used to lift the victim three feet from the water to the pier so CPR could

The Bureau Diving Advisory Committee governs diving standards and activities and sponsors the biennial dive seminar. DAC team leaders are (l-r): Jim Doty (PN Region), Max Groom (LC Region), Russ Smith (LM Region), Bill Karsell (SW Region), Larry Boll (MP Region), and chairman Dick Crysdale (E&R Center). Ron Searle, Chief, Division of Safety, is not pictured.

Diving instructor Bob Wohlers (sitting on dock) explains proper buoyancy.

continue. For a diver, training like this can mean the difference between life and death, or permanent disability.

Throughout the open water exercises, the divers rotated diving buddies so the least experienced could dive with those who have more experience, thereby helping new divers learn more skills, become more familiar with different types of equipment, and develop greater self-confidence. Having confidence in a dive buddy is important because there is less anxiety, fear and stress when diving in adverse conditions. The payoff from divers working together in these seminars comes when they are called together for multi-regional dive efforts, such as complex inspections of dams.

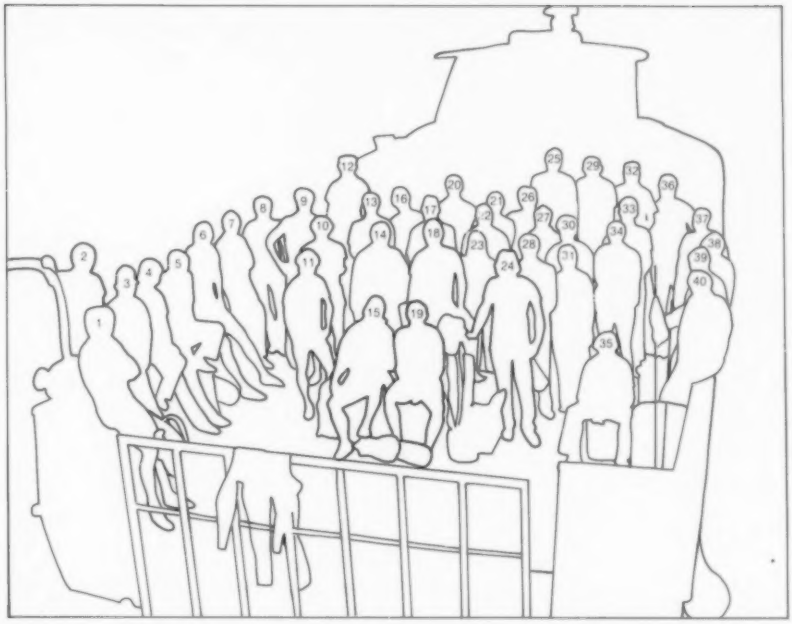
The seminar highlighted the special strength of the Bureau dive team — a diversity of professional skills. Civil and mechanical engineers who are familiar with the designs and workings of Bureau structures can quickly diagnose problems, take immediate corrective action if necessary and recommend preventive actions before problems become severe.

Dive partners carefully check each other's equipment for proper donning and operation before they enter the water.

Geologists on the team can monitor the degree of sloughing, slumping and change in erosional patterns in stilling basins and streams.

The most recent additions to the team are three botanists from the Environmental Sciences Section, Division of Research, at the Engineering and Research Center. Fred Nibling, Joan Thullen and John Boutwell are using their diving abilities to study the rapid spread of hydrilla and eurasian watermilfoil — weeds that are a major threat to water conveyance systems. These Asian aquatics are choking off and causing substantial water losses in our water conveyance

(Left to right) Divers Joan Thullen, John Boutwell and Fred Nibling enter the hyperbaric decompression chamber for a simulated 165-foot dive. Dr. Andy Pilmanis (background) will monitor the dive.



The entire dive team gathers for a photograph on the "Westerly" at the close of the biennial seminar. (1) Jim Doty; (2) Brent Carter; (3) Fred Nibling; (4) David Allen; (5) Ron McKown; (6) Tom Lincoln; (7) Tom Spicher; (8) Larry Boll; (9) Dave Samuelson; (10) Bob Wohlers; (11) John Boutwell; (12) Dennis Graver; (13) Russ Smith; (14) Dick Crysdale; (15) Chris Woegens; (16) Joel Sturm; (17) Hugh Winder; (18) Alan Solbert; (19) Doug Eller; (20) Bill Karsell; (21) Jim Andrews; (22) Don Nelson; (23) Joan Thullen; (24) Bill Duncan; (25) Bill Butler; (26) Brian Jobson; (27) Rich Kristof; (28) Dennis Christenson; (29) Howard Carver; (30) Ernie Lendenmann; (31) Cherry Beasley; (32) Max Groom; (33) Alan Jensen; (34) Doug Troudeau; (35) Bill Stine; (36) Gordon Mueller; (37) Guy Grooms; (38) Dan Wilson; (39) Chris Peterson; (40) Gray Bryant.

systems in the western United States. The botanists also are studying the environmental feasibility of controlling these aquatics with hybrid grass carp. The study requires extensive diving in canals throughout the Bureau's seven regions as this aquatic menace spreads. Hopefully, early detection of these aquatics by divers can slow or stop the spread of these weeds.

There are also environmental specialists, wildlife biologists and an archeologist on the team.

The seven dive seminars held since the Bureau dive teams formed have effectively honed the diving and professional skills of team members. Because of these "western water guardians," the task of collecting, conveying, storing and using our most precious resource — water — continues smoothly.

Reclamation Resource Review

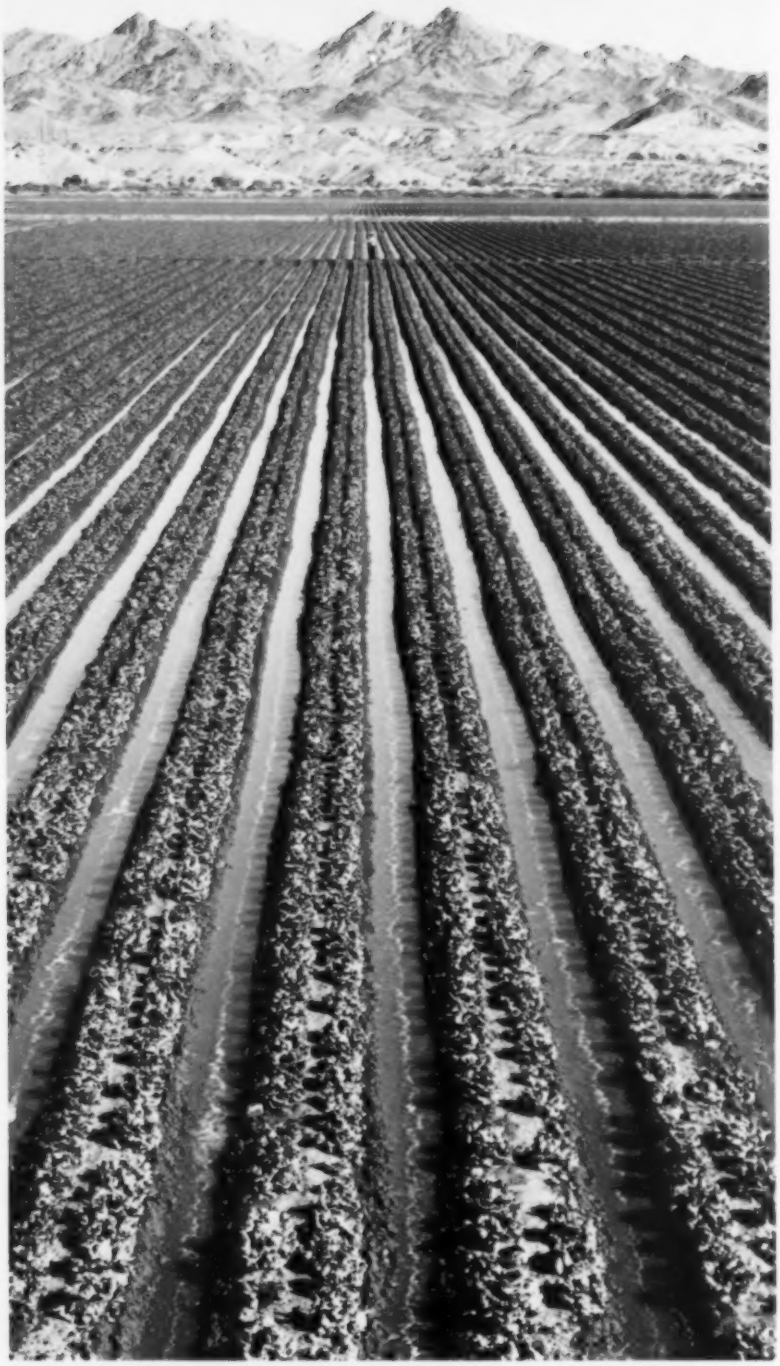
The year 1980 was a banner year for the Bureau of Reclamation. The Bureau's water projects provided an abundance of water for cities and towns, irrigation and crop production, recreation and electrical energy.

The Bureau of Reclamation, providing the water to meet these needs, amassed some astounding statistics during 1980:

Bureau projects delivered 30.2 million acre-feet of water across the 17 western states. Of this, 27.5 million acre-feet was used by agriculture for irrigation. Two million acre-feet went to municipal and industrial users. A total of 700,000 acre-feet was used for other purposes . . . livestock water, construction contracts.

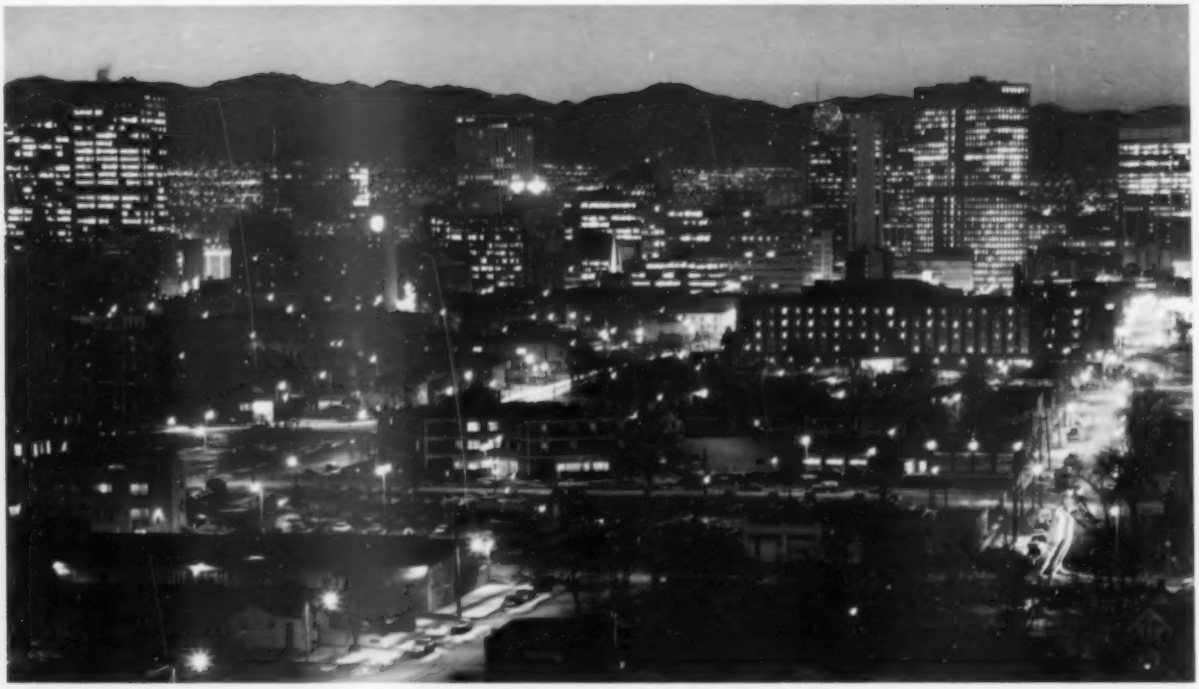
A record 22.1 million people used Bureau of Reclamation water . . . 19 million received municipal and industrial water and 3.1 million received irrigation service on urban and residential, commercial and industrial lands and on full and part-time irrigated farms.

The Bureau's 286 recreation areas recorded 66.5 million visitor days, valued at nearly $300 million.



Irrigation service was available to 11,944,000 acres of land — actual irrigated acres totaled 10,093,000.

A total of $7.4 billion (54.5 million tons) in crops were harvested from lands served by Reclamation waters.

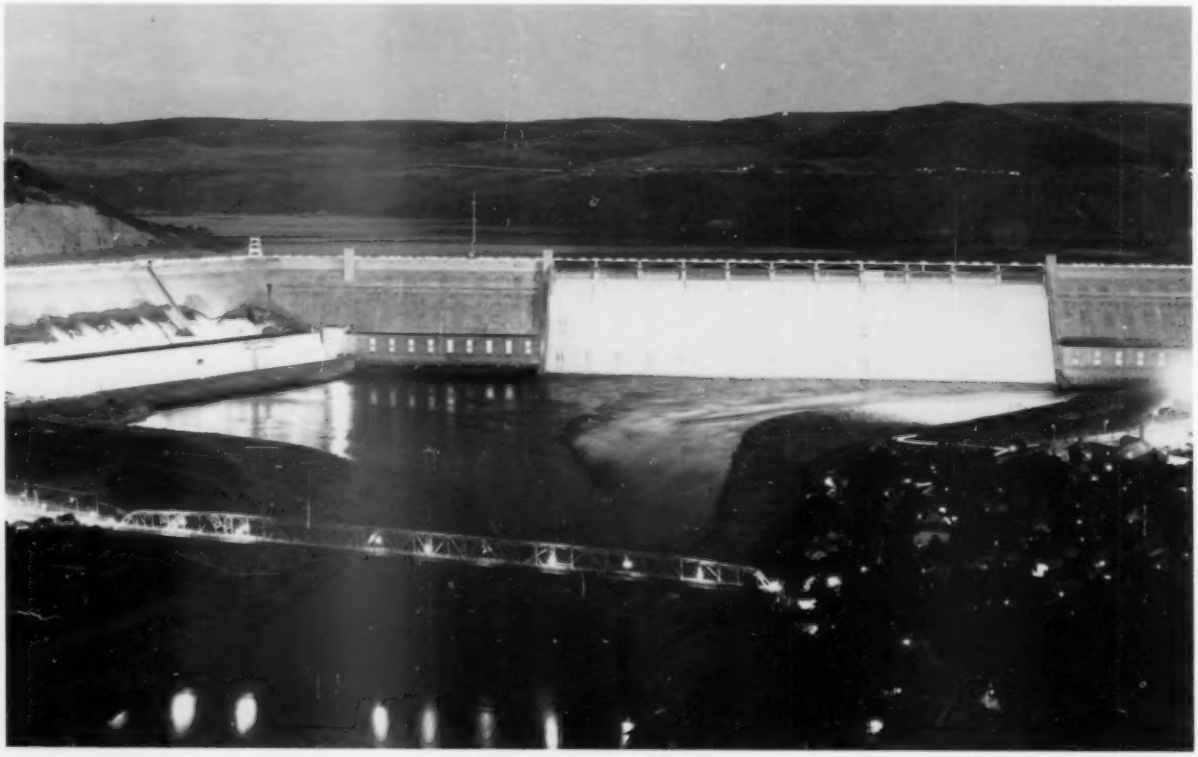


Direct economic benefits totaled more than $10 million during 1980 alone, and have exceeded $100 billion since 1902.

Estimated flood damages prevented by Reclamation facilities amounted to $177.7 million.

Bureau powerplants having a total installed capacity of 12.8 million kilowatts generated 46 billion kilowatt-hours of electricity.

The Bureau awarded $373 million in new construction contracts. As of September 30, 1980, $8.6 billion in construction costs have been invested in Bureau projects. Of that amount $1.8 billion has been repaid to the U.S. Treasury through matured repayment contracts and power revenues.



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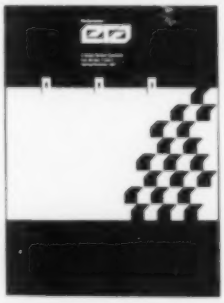

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